Population Parameters of *Ganaspidium utilis* Beardsley (Hymenoptera: Eucoilidae) on *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae)

Lekhnath Kafle[1], Po-Yung Lai[1]* and Yin-Fu Chang[2]

[1] Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, Neipu, Pingtung 91201, Taiwan ROC

[2] Asian Vegetable Research and Development Center, Shanhua, Tainan 74199, Taiwan ROC

*Corresponding author (E-mail: pylai@mail.npust.edu.tw)

ABSTRACT

This study was aimed at determining the population parameters of *Ganaspidium utilis*, a parasitoid of *Liriomyza trifolii*, under the laboratory conditions at 17±2°, 25±2° and 29±2°C. The developmental time of *G. utilis* was longest (32.85±0.86 days) at 17±2°C and shortest (14±0.44 days) at 29±2°C. The developmental time between a male and a female *G. utilis* under the tested temperatures was not significantly different. The longevity of male and female *G. utilis* significantly decreased as the temperature increased. The overall fecundity and sex ratio of the offspring of *G. utilis* were also affected by the variation in temperature. Results of the population parameter analysis showed that 25±2℃ was the most favorable temperature for *G. utilis* to multiply in laboratory conditions. The temperatures at 17±2° and 29±2 ℃ caused lower net reproduction rate of *G. utilis* than 25±2℃. The mean generation time, finite rate of increase and population-doubling time of *G. utilis* had an inverse relationship with temperature; however, the intrinsic rate of increase of *G. utilis* showed a positive relationship with temperature. According to its population parameters, demonstrated in this study, *G. utilis* has a good potential to be an effective natural enemy for the control of *L. trifolii*.

Key words: Parasitoid, *G. utilis*, *L. trifolii*, Population parameters.

INTRODUCTION

Liriomyza sativae (Blanchard), *L. trifolii* (Burgess), *L. huidobrensis* (Blanchard), *L. bryoniae* (Kaltenbach), and *L. strigata* (Meigen) are economically important leafminers (Spencer, 1973). Chien (1997) reported that *L. trifolii*, *L. bryoniae*, and *L. sativae* caused serious damage to ornamentals and vegetables between 1984 and 1995 in Taiwan.

Ganaspidium utilis is a larva-pupal endoparasitoid that was introduced into Hawaii from the Weslaco area of Texas for the control of *L. trifolii* and *L. sativae* (Nakao and Funasaki, 1979). It successfully became established in Hawaii, the Marianas, Tonga, and Guam and has become an important natural enemy of *Liriomyza* spp. (Lai and Funasaki, 1986; Greathead and Greathead, 1992; Johnson, 1993).

In 2003, *G. utilis* was introduced to Taiwan from Hawaii. Upon arrival, the parasitoids were isolated in the quarantine

laboratory of National Pingtung University of Science and Technology (NPUST) and were kept under observation to study their biology and parasitism. Previous studies described the biology of *G. utilis* using *L. sativae* as a host (Petcharat and Johnson, 1988). A cost effective method for the mass production of *G. utilis* was also developed (Rathman *et al.*, 1991). However, life table and population parameters of this parasitoid have not been reported previously. Therefore, the objective of this study was to describe the life table and population parameters of *G. utilis* under laboratory conditions using *L. trifolii* as the host.

Life table studies are fundamental not only to understand demography but also to know the general biology. In such studies, development times and survival rates, longevity of adults and the daily fecundity of females are recorded for every individual (Chi, 1988). Knowledge of the development rate and life history of a parasitoid can be used, along with other developmental parameters such as fecundity and longevity, to estimate the potential impact of the parasitoid on host populations (Martin *et al.*, 1989; Bernal and González, 1993). Life tables can be used to compare the biological traits of parasitoids submitted to variations on biotic and abiotic factors such as temperature, adaptability to host and reproductive potential of parasitoids, and other insect species (Maceda *et al.*, 1994; Pratissoli and Parra, 2000; Pratissoli *et al.*, 2004).

The components of a life table typically include the numbers entering each of several life stages (l_x) in an insects life cycle, numbers dying within each stage (m_x) due to specific factors, together with estimates of rates of lose in each stage (Southwood, 1978). The population parameters as described by Carey (1993) were: the net reproductive rate (Ro), is defined as the mean number of daughters produced per cohort of females over their lifetimes. Similarly, the mean generation time (T) is the average interval separating the births of one generation from the births of the next, the intrinsic rate of increase (r) is the maximum exponential rate of increase by a population growing within defined physical conditions, population increase at each time interval (λ) is defined as the ratio of population sizes at each time step, doubling time (t) is the time needed for a population to double in size from a fixed point in time.

MATERIALS AND METHODS

Using *L. trifolii* larvae as test insects

Throughout this study, the same procedures were followed to obtain the late 2nd or early 3rd instar *L. trifolii* larvae as test insects. Six pairs of *Phaseolus* Henderson lima bean plants (2 leaves each) were placed for 6 hours in a screened cage containing 50~60 *L. trifolii* adults. After 6 hours, the bean plants were removed from the cage and were held for 5 days to allow the *L. trifolii* eggs to hatch and develop until they reached the late 2nd or early 3rd instar.

Rearing of *G. utilis*

Ganaspidium utilis parasitoids used in this study were obtained from a laboratory culture using *L. trifolii* as the host insect. The *L. trifolii* colony was maintained in the laboratory using methods described by Rathman *et al.* (1991). *Ganaspidium utilis* was reared using methods described by Petcharat and Johnson (1988). Stems of *L. trifolii* infested bean plants (2 leaves each) were cut immediately above the roots and placed in a 200 ml flask filled with water. A honey-water solution (25%) was sprayed on the lima bean leaves as a food source for the adult parasitoids. Plants were exposed to *G. utilis* for 24 hours and then removed. The leaves were cut at the base and kept in closed plastic containers to allow the *L. trifolii* larvae to pupate. Leafminer puparia were collected and held in a petri dish (9 cm diameter) until the *G. utilis* adults emerged. Parasitoid adults were returned to the oviposition cages for either culture maintenance or were used in subsequent studies.

The rearing of *L. trifolii* and *G. utilis* was conducted in a laboratory at 25±2°, 50±10 % RH and a photoperiod of 14L: 10D.

Survivorship of *G. utilis*

For this study, 2 lima bean plants infested with late 2nd or 3rd instar larvae of *L. trifolii* were placed into a container, containing 10 pairs of adult parasitoids. After 24 h, exposed leaves were removed and new 50 late 2nd or early 3rd instar leafminer larvae were added. This was done daily until the female parasitoid died. The number of days that a female lived was recorded.

This study was replicated 4 times. Means were compared by using t-test and SNK test of SAS (2003).

Longevity of *G. utilis*

Two leaves containing about 50 late 2nd or early 3rd instar leafminer larvae were used. Leaves were placed in a cage, and newly emerged male and female parasitoids were paired and released into the cage. After 24 h, exposed leaves were removed, and 50 new late 2nd or early 3rd instar leafminer larvae were added. This was done daily until the female parasitoid died. A honey-water solution (25%) was provided to the males until they died. The numbers of days that males and females lived were recorded.

This study was replicated 4 times. Means were compared by using t-test and Student-Newman-Keuls (SNK) test of SAS (2003).

Fecundity and sex ratio of *G. utilis*

Using leaves exposed during the experiment on the longevity of parasitoids, the fecundity and sex ratio were determined. The exposed leaves were held in a petri dish (9 cm diameter) until the leafminer larvae pupated. The puparia were collected and held until adult parasitoids or leafminers emerged. The number of *G. utilis* emerging and the sex ratio were recorded daily. The emerging parasitoids were sexed under a microscope using antennal characteristics as described in Beardsley (1988). The sex ratio was calculated as the fraction of the male offspring to the total number of offspring, as shown in equation 1.

$$\text{Sex ratio} = m/(m+f) \quad (1)$$

Where, m is the number of males produced and f is the number of female offspring produced by *G. utilis* female.

This study was replicated 4 times. Means were compared by using SNK test techniques of SAS (2003).

Determination of population parameters

Data obtained during the study of biological characters of *G. utilis* were used to analyze the population parameters by using procedures reported by Krebs (1978) and Birch (1948). Facing the difficulty in obtaining information on parasitoid development inside the host pupa, the overall percentage of survival of immature stages was estimated by applying the method reported by Rossa *et al.* (2002) by

subtracting the number of *L. trifolii* adults emerged, the number of parasitoids emerged and the number of naturally dead pupae from the total pupae offered.

Net reproductive rate (R_o)

R_o is the average number of female offspring born to the insects considered at age 0. Consider n newborn insects. Some of them will die without producing any offspring (zero offspring), others will produce one or several offspring. R_o is the average number of female offspring produced by a birth cohort of females in their lifetime.

$$Ro = \sum_{x=0}^{n} lxmx \qquad (2)$$

Where, x is age (days); l_x is probability of surviving to age x and m_x is the no. of female offspring born to a mother of age x.

Intrinsic rate of increase (r)

The intrinsic rate of increase (r) is the maximum exponential rate of increase by a population growing within defined physical conditions. The r value was determined by applying the Lotka-Euler equation developed by Birch (1948).

$$\sum e^{-rmx} lxmx = 1 \qquad (3)$$

Where, e = natural base = 2.71878 (a constant).

Mean generation time (T)

The Mean generation time (T) is the average interval separating the births of one generation from the births of the next.

$$T = \log_e(Ro)/r \qquad (4)$$

Where, e = natural base = 2.71878 (a constant) and r = per capita rate of population change

Population doubling time (t)

Population doubling time (t) is the time needed for a population to double in size from a fixed point in time.

$$\ln(2.0) = rt \qquad (5)$$

Where, ln (2.0) is a constant = 0.69315.

Therefore, the time it takes for an exponentially growing population to exactly double in size, regardless of the absolute size of the population will be:

$$t = 0.69315/r \qquad (6)$$

Where, e = natural base = 2.71878 (a constant), r = per capita rate of population change and and t = time in the same units as r.

3.6.5. Finite rate of increase (λ)

Finite rate of increase (λ) is defined as the ratio of population sizes at each time step.

$$Ro = \lambda^T \qquad (7)$$

Where, R_o = Net reproductive rate and T = Mean generation time.

RESULTS

Developmental time of *G. utilis*

The total developmental time of male *G. utilis* significantly decreased as 34.95±1.21 to 13.22±0.2 days when the temperature increased from 17±2°C to 29±2°C. This trend was also observed in case of male *G. utilis* too. The total developmental time of male *G. utilis* significantly decreased as 30.75±0.95 to 15.37±0.75 days when the temperature increased from 17±2°C to 29±2°C. The days required for males and females of *G. utilis* offspring to emerge from puparia were not significantly different at the temperatures tested (Table 1).

Longevity and fecundity of *G. utilis*

The males and females of *G. utilis* lived longest at 17±2°C and shortest at 29±2°C. There was no significant deference in the longevity of male and female *G. utilis* across the temperatures (Table 1).

Results of this study on the fecundity of a *G. utilis* female revealed that the highest number of male and female offspring produced was at 29±2℃. The total number of progeny produced was highest and lowest at 29±2° and 17±2℃, respectively. The total number of progeny produced at 29±2° and 25±2℃ was not significantly different. The sex ratio of newly emerged progeny decreased from 0.62 to 0.59 as temperature increased from 17±2° to 29±2℃ (Table 1).

Population parameters of *G. utilis*

The *G. utilis* females demonstrated similar survival trends across the temperatures (Fig. 1). Mortality of *G. utilis* females occurred faster at 29±2°C than at 25±2° and 17±2℃. The short adult lifespan at 29±2℃ suggested that *G. utilis* was more sensitive to warmer temperatures. The extended longevity of adult *G. utilis* at 17±2℃could be explained by reduced activity, less energy utilized for reproduction, or both. *G. utilis* females did not produce progeny at first 2 days after emergence at 17±2°C; however, *G. utilis* females produced progeny immediately after the emergence at 25±2° and 29±2℃ (Fig. 1). Daily progeny production was not uniform across the temperatures. Progeny production peaked during the first few days of adult life and then declined sharply at 17±2° and 25±2℃ and declined gradually at 29±2℃. The highest progeny production was attained on day 5 (2.5 progeny/female/day) at 17±2℃, day 6 (6.8 progeny/female/day) at 25±2℃ and day 2 (7.75 progeny/female/day) at 29±2℃ (Fig.1). With in the half-life of *G. utilis* female, about 71, 64 and 74 % of the progenies were produced at 17±2°, 25±2° and 29±2°C, respectively.

The life table of *G. utilis* demonstrated an inverse relationship between the mean generation time (T) and the temperature (Table 1). T was highest at 37.33 days at 17±2°C decreased to 22.93 days at 25±2°C and then to 18.28 days at 29±2°C (Table 1). The net reproductive rate (R_o) of *G. utilis* was highest at 33.55 at 25±2°C, then followed by 26.22 at 29±2°C and 6.17 at 17±2°C. The finite rate of increase (λ) of *G. utilis* showed a positive relationship with the temperatures. *G. utilis* demonstrated highest finite rate of increase (number of females added to the population per female) at 29±2°C. The intrinsic rate of increase (r) of *G. utilis* increased with the increase of temperature. At 17±2°C, r was 0.049, which increased 3.2 times (0.157) at 25±2°C and 3.67 times (0.18) at 29±2°C, and the maximum capacity of population increase was at 29±2°C. Population doubling time was shortest at 3.85 days at 29±2°C, which increased to 4.41 days at 25±2°C and 14.46 days at 17±2° C (Table 1).

DISCUSSION

Chien and Ku (2001b, c) reported that the longevities of *H. varicornis* were 22.4 ± 0.6 (female) and 14.5 ± 1 days (male), and for *N. formosa* were 22.3 ± 1.2 (female) and 7.5 days (male) at 25°C. Similarly, Lopez *et al.* (2004) reported that the longevities of *Halticoptera circulus* (Walker), an imported parasitoid form Hawaii to Taiwan, were 34.25 ± 4.92 (female) and 14.25 ± 2.36 days (male) at 26°C. Petcharat and Johnson (1988) also observed longevities of 8.9 ± 1.4 (male) and 8.8 ± 2 days (female) for *G. utilis* at 26°C. The longevity of females observed in this study was higher than that reported by Petcharat and Johnson (1988) but lower than the rest of the other parasitoids mentioned above at both temperatures.

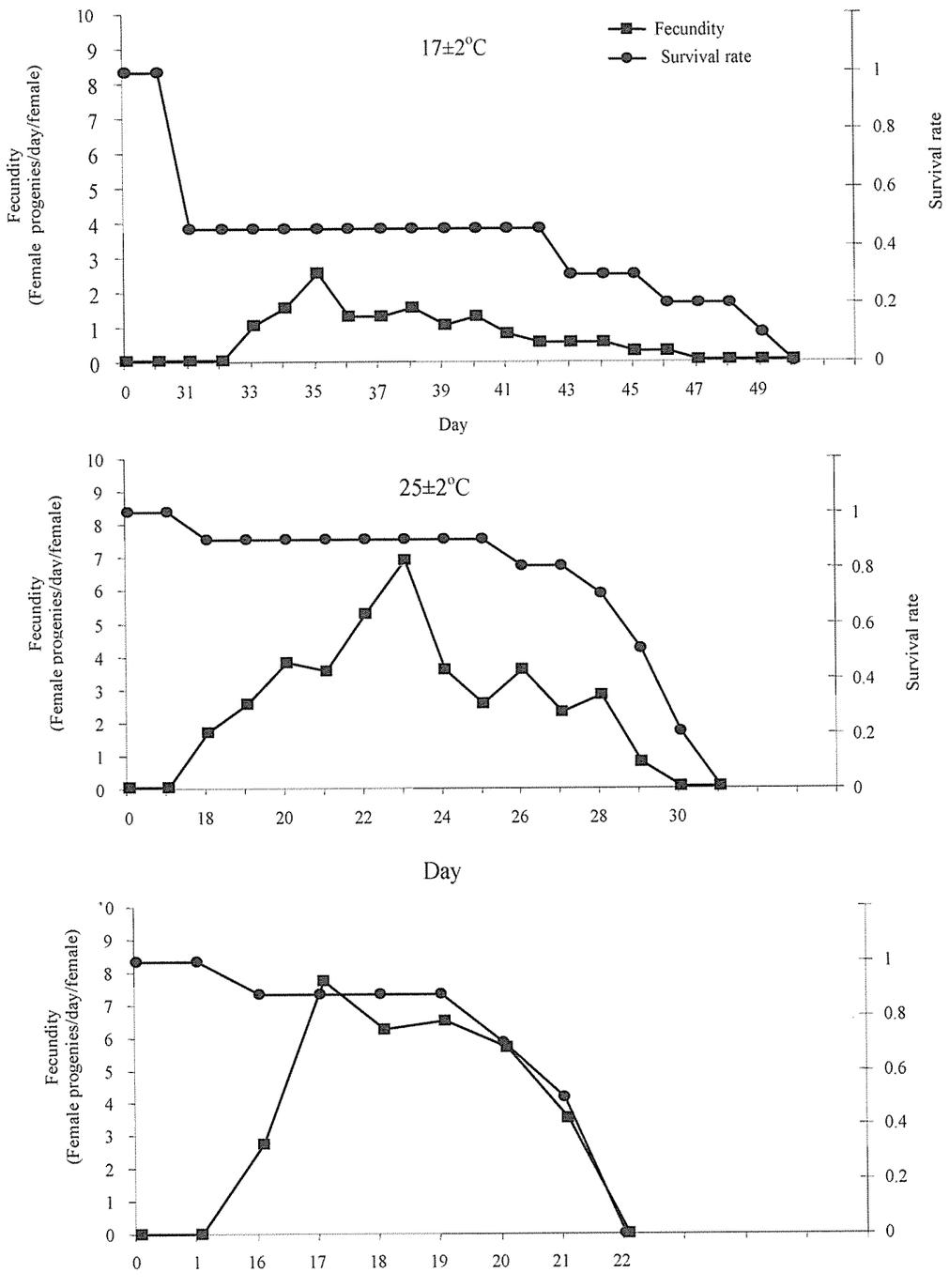

Fig. 1. Fecundity and survivorship of *G. utilis* at different temperatures.

Table 1. Life history parameters of *G. utilis* at different temperature.

Parameters	17±2°C*	25±2°C	29±2°C
Developmental time (days)			
Male	34.95±1.21Aa	18.83±1.59Ab	13.22±0.2Ac
Female	30.75±0.95Aa	17.33±1.26Ab	15.37±0.75Ac
Longevity (days)			
Male	16.5±2.08Aa	10.5±3.42Ab	5.25±1.26Ac
Female	19±2.16Aa	12.87±2.9Ab	7.12±1.93Ac
Progeny produced			
Male	23±6.27Ab	27.79±8.35Bb	46±4.32Aa
Female	14±3.1Ab	38.87±8.66Aa	32.5±3.1Aa
Total	37±9.05b	66.67±8.5a	78.5±7.1a
Sex ratio (male/male + female)	0.62	0.42	0.59
Population parameters			
Net reproductive rate R_o	6.17	33.55	26.22
Mean generation time (days) T	37.33	22.93	18.28
Finite rate of increase λ	1.05	1.17	1.19
Intrinsic rate of increase r	0.049	0.157	0.18
Population doubling time (days) t	14.46	4.41	3.85

* Means followed by different letters in the same row (lower case) or in the same column (upper case) are significantly different by SNK test ($P<0.05$).

Developmental times varied between *H. varicornis* (11.1 ± 0.1 days) and *N. formosa* (14.4 ± 0.2 days) at 25°C (Chien and Ku 2001b, c), and *H. circulus* (31.57 ± 4.49 days) and *G. utilis* (25.9 ± 1.4 days) at 26°C (Petcharat and Johnson, 1988; Lopez *et al.*, 2004). The developmental time observed in this study was lower than that of *G. utilis* observed by Petcharat and Johnson (1988) and *H. circulus* by Lopez *et al.* (2004), but was similar to or higher than those of *H. varicornis* and *N. formosa* (Chien and Ku, 2001b, c).

The mean number of progeny produced per female also varied with the parasitoid species at 204 ± 22 (*H. varicornis*) and 202 ± 18 (*N. formosa*) at 25℃ (Chien and Ku, 2001b, c), and 145.25 ± 0.67 (*H. circulus*) and 51.4 ± 13.8 (*G. utilis)* at 26℃ (Petcharat and Johnson, 1988; Lopez *et al.*, 2004). In comparison with other parasitoids, the progeny production observed in this study was higher than that reported by Petcharat and Johnson (1988) and lower than the other reports at both temperatures.

The female sex ratios were reported to be 0.62 *(H. varicornis*) and 0.54 (*N. formosa)* at 25°C (Chien and Ku, 2001b, c), and 0.67 (*H. circulus)* and 0.58 (*G. utilis*) at 26°C (Petcharat and Johnson, 1988; Lopez *et al.*, 2004). The female sex ratio of *G. utilis* observed in this study (0.58) was similar to that observed by Petcharat and Johnson (1988), but higher than that of *N. formosa* at 25 ± 2°C (Chien and Ku, 2001c).

Because of the highest net reproductive rate, detected at 25±2°C, this temperature was the most favorable temperature for multiplying the *G. utilis* in laboratory (Table 1). Because of the shortest longevity, shortest developmental time and highest intrinsic rate of increase, the population of *G. utilis* could be doubled in 3.85 days at 29±2°C (Table 1). Many researchers reported that the optimal temperature of a parasitoid can be expressed by their optimum growth and development, fecundity and longevity at

certain temperature ranges. It is also reported that the temperature affects negatively on average generation time, finite rate of increase and population doubling time and positively on the intrinsic rate of increase of parasitoids (Froud and Stevens, 1997; Olaye *et al.*, 1997; Pratissoli and Parra, 2000; Olaye *et al.*, 2001; Pratissoli *et al.*, 2004).

At 25℃, the intrinsic rate of increase (r) for *L. trifolii* (0.2329) was, higher that the r value of *G. utilis* (0.157) (Chien and Ku, 1996). This resulted the several overlapping generations in the same population of *L. trifolii*. Therefore, *G. utilis* females can easily find host to lay their eggs. Based on the results, the intrinsic rate of increase of *G. utilis* that obtained from 3 different temperatures were lower as compared with other hymenopteran parasitoids including *Tamarixia radiata* (0.2948) (Chein *et al.*, 1994), *Tekenomus isis* (0.203) (Olay *et al.*, 2001), *Trichograma pretiosum* (0.32), *T. acacioi* (0.35) (Pratissoli and Parra, 2000), *T. busseolae* (0.258) (Olaye *et al.*,1997) and *Thripobius semiluteus* (0.1101) (Froud and Stevens, 1997). Based on the results, the intrinsic rate of increase of *G. utilis* that obtained from 3 different temperatures were positively co-related with temperature. The positive effect of temperature on the intrinsic rate of increase were also reported by many researchers for other parasitoids including *T. radiata* (Chein *et al.*, 1994), *T. isis* (Olay *et al.*, 2001), *T. pretiosum*, *T. acacioi* (Pratissoli and Parra, 2000), *T. busseolae* (Olaye *et al.*, 1997) and *T. semiluteus* (Froud and Stevens, 1997).

CONCLUSIONS

As it was demonstrated in this study, depending upon the temperature, a female of *G. utilis* lives between 1 to 3 weeks and lays eggs throughout its lifespan. Once *G. utilis* population established in field, the colonization and dispersal will be fasters because *G. utilis* population could be doubled within 4 to 14.5 days, depending upon the temperature. Because of the shorter population doubling time, several generations of *G. utilis* could be overlapped in a population. This attribute may be beneficial to the control of *L. trifolii* as its population also known to be overlapped in the field. Because of the lower female sex ratio, it would require more *G. utilis* females being released in the field to achieve a significant control of *Liriomyza* leafminers. Based on the biological characteristics and parasitization performance observed in this study *G. utilis* can be considered as a potentially effective biological control agent of *L trifolii* at 25±2 and 29±2°C, which are favorable for the activities of *G. utilis*.

REFERENCES

Beardsley, J. W. 1988. Eucoilid parasites of Agromyzidae leafminer in Hawaii (Hymenoptera: Cynopoidea). Proc. Hawaii. Entomol. Soc. 28:33-47.

Bernal, J. and D. González. 1993. Temperature requirements of four parasites of the Russian wheat aphid *Diuraphis noxia*. Entomol. Exp. App. 69: 173-182.

Birch, L. C. 1948. The intrinsic rate of natural increase of an insect population. *J. Anim. Ecol. 17*: 15-26.

Carey, J. R. 1993. Applied Demography for Biologists with Special emphasis on Insects. Oxford University Press, Oxford. p.224.

Chein, C. C., Y. I. Chu and H. C. Ku. 1994. Influence of food on longevity, egg production and population increase of the eulophid wasp, *Tamarixia radiate.* Plant Prot. Bull. 36:97-105.

Chi, H. 1988. Life table analysis incorporating both sexes and variable development rates among individuals. Environ. Entomol. 17:26-34.

Chien, C. C. 1997. Current occurrence and control of Liriomyza leafminers in Taiwan. *Proceedings on Symposium on Plant Protection between the Taiwan cross strait.* May. 29-30, 1997. Taiwan Agricultural Research Institute, Taichung, Taiwan, R.O.C. p. 79-94. (In Chinese with English abstract)

Chien, C. C. and S. C. Ku. 1996. Morphology, life history and reproductive ability of *Liriomyza trifolii* (Diptera: Agromyzidae). J. Agri. Res. China. 45:69-88. (In Chinese with English abstract)

Froud, K. J. and P. S. Stevens. 1997. Life table comparison between the parasitoid *Thripobius semiluteus* and its host Greenhouse thrips. *Proceedings of the 50th conference of The New Zealand Plant Protection Society Incorporated.* The Horticulture and Food Research Institute of New Zealand Limited, Private Bag 11030, Palmerston North, New Zealand. p. 232-235.

Greathead, D. J. and A. H. Greathead.1992. Biological control of insect pests by insect parasitoids and predators: The BIOCAT Database. Biocon. News Info.13:61-68.

Johnson, M. W. 1993. Biological control of *Liriomyza* leafminers in the pacific basin. Micronesica Suppl. 4:81-92.

Krebs, C. J. 1978. Ecology: The Experimental Analysis of Distribution and Abundance. 2nd Ed. Harper and Row, New York. p. 678.

Lai, P. Y. and G. Y. Funasaki. 1986. Introductions for biological control in Hawaii: 1983 and 1984. Proc. Hawaii Entomol. Soc. 26:89-91.

Maceda, A., C. L. Hohmann and H. R. Santos. 1994. Comparative life table for *Trichogramma pretiosum* Riley and *Trichogramma annulata* De Santis (Hym.: Trichogrammatidae). Revista do Setor de Ciências Agrárias. 13: 279-281.

Martin Jr., W. R., D. A. Nordlund and W. C. Nettles Jr. 1989. Influence of host development state on host suitability and reproductive biology of the parasitoid *Eucelatoria bryani.* Entomol. Exp. App. 50: 141-147.

Nakao, H. K. and G. Y. Funasaki. 1979. Introductions for biological control in Hawaii:1975 and 1976. Proc. Hawaii Entomol. Soc. 23:125-128.

Olaye, A. C., F. Schulthess, H. M. Poehling and C. Borgemeister. 2001. Factors affecting the biology of *Telenomus isis* (Polaszek) (Hymenoptera: Scelionidae), an egg parasitoid of cereal stem borers in West Africa. Bio. Con. 21: 44-54.

Olaye, A. C., F. Schulthess, T. G. Shanower and N. A. Bosque-Pe´ Rez. 1997. Factors influencing the developmental rates and reproductive potentials of *Telenomus busseolae* (Gahan) (Hym.: Scelionidae), an egg parasitoid of *Sesamia calamistis* Hampson (Lep.: Noctuidae). Bio. Con. 8: 15-21.

Petcharat, J. and M. W. Johnson. 1988. Biology of the leafminer parasitoid *Ganaspidium utilis* Beardsley (Hymenoptera: Eucoilidae). Ann. Entomol. Soc. Am. 81:477-480.

Pratissoli, D. and J. R. P. Parra. 2000. Fertility

and life table of *Trichogramma pretiosum* (Hym.: Trichogrammatidae) in eggs of *Tuta absoluta* and *Phthorimaea operculella* (Lep.: Gelechiidae) at different temperatures. J. Appl. Entomol. 124:330-342.

Pratissoli, D. J. C. Z., R. V. Ulysses, S. A. Josimarde, M. G. Edylene and C. E. Marcelo. 2004. Fertility life table of *Trichogramma pretiosum* and *Trichogramma acacioi* on eggs of *Anagasta kuehniella* at different temperatures. Pesq. Agropec. Bras. 39: 193-196.

Rathman, R. J., M. W. Johnson and B. E. Tabashnik. 1991. Production of *Ganaspidium utilis* (Hymenoptera: Eucoilidae) for biological control of *Liriomyza* spp. (Diptera: Agromyzidae). Biol. Con. 1:256-260.

Rossa, F. O. R. L., D. C. Crespo and R. E. Lecuona. 2002. Population parameters of *Spalangia endius* Walker (Hymenoptera:Pteromalidae) on pupae of *Musca domestica* L. (Diptera: Muscidae). Neotropical Entomology 3:597-600.

SAS Institute. 2003. SAS user's guide: Statistics, version 8 ed. SAS Institute, Inc., Cary, NC.

Southwood, T. R. F. 1995. Ecological methods. 2nd. ed., London, Chapman and Hall. p.524.

Spencer, K. A. 1973. Agromyzidae (Diptera) of economic importance. The Hague, Netherlands. 418pp.